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Are Corn Trend Yields Increasing at a Faster Rate?

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INTRODUCTION

Crop yields are affected by a complex combination of factors, such as weather, seed genetics, and producer-level management techniques. Despite this complexity, yields tend to show a general increase over time, which is commonly referred to as the "trend yield."

There has been considerable discussion in the agricultural community that improved technology has caused corn trend yields to increase at an increasing rate in recent years. Many farmers, crop experts, and seed companies credit biotechnology-driven improvements in seed genetics for the recent corn yield increases (Fitzgerald 2006).

Figure 1 provides an example of the empirical evidence often used to support a conclusion that corn yields since the mid-1990s have increased at an increasing rate relative to prior decades. As a result, there has been fairly widespread acceptance that a new and higher trend began in the mid-1990s and it should be used as a starting point for estimating future yields. While higher yields might be due to a new trend, such claims should be treated with caution since weather can have a large effect on trend yields estimated over short periods of time (Nielsen 2006).

The purpose of this brief is to investigate whether trend yields in the U.S. Corn Belt have accelerated since the mid-1990s. The effect of both weather and technology on corn yields is estimated over a relatively long time period, 1960-2007, for three important corn producing states, Illinois, Iowa, and Indiana.

TREND ANALYSIS

Regression models were developed to estimate the separate effects of weather and technology on state-average corn yields in Illinois, Indiana, and Iowa over 1960-2007.[1] The three states were selected because they have similar weather and crop development time-scales and together they represent nearly half of U.S. corn and soybean production. A linear time trend variable was used as a proxy for technology. Weather variables included pre-season precipitation (September-April) and May through August monthly precipitation and temperature. The model specifications were based on the well-known work of Thompson (1963 1969 1970 1986).

[1] The analysis presented in this brief is based on the models and tests found in the research report by Tannura, Irwin, and Good (2008). The main difference is that the analysis reported here includes the recently available 2007 yield and weather observations. See the research report by Tannura, Irwin, and Good for a detailed discussion of the regression models and estimation results for 1960-2006.

Estimation results indicated that the models explained between 94 and 95% of the variation in corn yields for the three states. The results revealed that corn yields in the three states were particularly affected by technology, the magnitude of precipitation during June and July, and the magnitude of temperatures during July and August. Analysis of the estimated models showed that unfavorable weather reduced yields by a much larger amount than favorable weather increased yields. For example, 2 inches higher than average July precipitation in Illinois increased corn yields 6 bushels per acre, while 2 inches less than average reduced yields 16 bushels per acre.

Panel A of Figure 2 shows trend yield estimates for each state over 1960-2007. It is important to emphasize that these trend yield estimates were adjusted for the effect of weather, and therefore, may differ slightly from trend yield estimates based only on a technology variable. Not surprisingly, trend yield estimates over the entire sample period were similar for the three states. Corn yields increased at the fastest rate in Iowa and Illinois, with annual increases of 2.1 and 2.0 bushels per year, respectively. Trend yield increases in Indiana were slightly lower at 1.7 bushels per year.

The regression models were re-estimated allowing separate trends before and after 1996. Panel B of Figure 2 shows the results of this analysis, which indicate that the trend in corn yields since 1996 changed by very small magnitudes: +0.2, 0.0, and +0.2 bushels per acre in Illinois, Indiana, and Iowa, respectively. At most, the models estimated that yield trends increased by about two-tenths of a bushel after adjusting for the effects of weather. Furthermore, none of the changes in trend were statistically significant. The sensitivity of the results was examined by also fixing the breakpoint at 1994, 1995, 1997, and 1998. The magnitude of the estimated change in trend yields was not sensitive to the alternative breakpoints.[2] In sum, the regression models did not indicate that a notable increase in trend yields for corn occurred in the mid-1990s.

How can we reconcile the lack of evidence for an increase in corn trend yields with the widespread perception that trend yields accelerated over the last decade? One possibility is that observers failed to recognize the impact of relatively favorable weather since the mid-1990s, and thereby, mistakenly attributed corn yield increases to technology. Figures 3, 4, and 5 show key weather variables for the three states over 1960-2007. The top panel in each figure shows total June-July precipitation and the bottom panel shows average July-August temperatures. The regression model results indicated that these were the most important precipitation and temperature variables for corn production in Illinois, Indiana, and Iowa.

The charts show that weather for the period from the mid-1990s forward was relatively favorable for corn production. With the exception of 2005 in Illinois and 2006 in Iowa, June-July precipitation was near average or above average. July-August temperature since the mid-1990s was average or below average, particularly for Iowa. The absence of pronounced upward temperature spikes, such as those occurring in 1980, 1983, 1988, and 1995, was especially noteworthy. In fact, the 1970s through the mid-1990s in each state had at least five years in which weather was less favorable for the development of corn than any year from 1996 through 2007.

By any reasonable standard, weather in the three states since the mid-1990s has been fairly benign for corn development. While there were areas of severe drought during

[2] It should be pointed out that trend increases associated with the 1998 and 1999 breakpoints for Illinois and the 1999 breakpoint for Iowa were statistically significant. However, the magnitude of the estimated trend increases was still small, only about two-tenths of a bushel.

some years (e.g., western Illinois in 2005), the scope of these weather events was limited. If this pattern is not well-understood or ignored, the relatively "high" yields since the mid-1990s can be easily attributed to technology instead of weather.

An alternative explanation for the regression results is that a shift to a higher trend in corn yields actually occurred in the last decade but there is not enough new data to detect the change. Two previous technological revolutions caused sharp jumps in trend yields (single cross hybrids in the late 1930s and nitrogen fertilizers in the late 1950s), so a shift would not be without historical precedent. As noted in the introduction, many farmers, crop experts, and seed companies credit biotechnology-driven improvements in seed genetics for recent corn yield increases.

Some experimental evidence provides support for the trend acceleration view. For example, Below et al. (2007) report that triple-stack corn varieties containing the bt-rootworm trait have a large yield advantage over non-bt varieties, as large as 50 bushels per acre. The authors note that yield advantages conferred by the rootworm trait are difficult to attribute entirely to rootworm control and hypothesize that the trait alters the corn plant's efficiency of nitrogen use. It is important to recognize that the experimental results reported by Below et al. are based on only one site (Urbana, Illinois) for one year (2007).

If the initial experimental results are confirmed, then widespread adoption of triple-stack corn varieties could well lead to an increase in trend yields. The June 2007 *Acreage* report prepared by the National Agricultural Statistics Service of the USDA indicated that stacked trait hybrids were planted on only 40%, 30%, and 37% of the corn acreage in Illinois, Indiana, and Iowa, respectively, in 2007.

The pattern in estimation errors for the corn regression models in recent years also provides some support for the view that trend yields have accelerated. As shown in Figure 6, errors in recent years have had a tendency to be positive (actual yields greater than predicted yields). Specifically, estimation errors for the Illinois corn model were positive five out of seven years since 2001 and averaged +3.5 bushels. Errors for the Indiana corn model were also positive five out seven years since 2001 and averaged +0.9 bushels. Errors for the Iowa corn model were positive all seven years since 2001 and averaged +6.1 bushels. While intriguing, these results should be viewed cautiously for two reasons. First, the magnitude of the average errors is not large, perhaps with the exception of Iowa. Second, positive or negative runs of similar lengths can occur randomly and are not unprecedented. For example, estimation errors for the Iowa corn model were positive every year over 1969-1973 and averaged +7.0 bushels.

FUTURE TREND PROJECTIONS

The regression analysis indicated that, after adjusting for the impact of weather, a notable increase in the trend rate of yield growth for corn in Illinois, Iowa, and Indiana was not yet evident in the data through 2007. At the same time, there is some experimental evidence from university trials and anecdotal evidence from producers that stacked trait corn hybrids may be increasing trend yields. So, what assumption should be used to project corn yields into the future? This question is important not only to individual producers, but also to current policy debates about the amount of additional acreage that will be needed for corn production in the future to meet ethanol-driven demand growth. (See Dhuyvetter, Kastens, and Schroeder (2008) for an example.)

To provide an historical perspective on the question, Figure 7 plots state-average corn yields for Illinois from 1940-2007 and three alternative scenarios for future yield trends through 2030. The 1940-2007 period is divided into two sub-periods, 1940-1959 and 1960-2007. The 1940-1959 period, which coincided with the widespread adoption of single-cross corn hybrids, had a trend yield growth rate of 1 bushel per year. The 1960-2007 period was characterized by the widespread adoption of nitrogen fertilizer and chemical herbicides and had a trend yield growth rate of 1.7 bushels per year, a 70% jump compared to 1940-1959.[3]

The first scenario simply projects the trend yield for 1960-2007, 1.7 bushels per year, over 2008-2030. It would result in a state-average trend yield of slightly less than 200 bushels per acre in 2030. This scenario is consistent with the test results from the weather and technology regression model. The second scenario assumes that biotechnology-driven improvements in seed genetics will increase the growth rate of trend yields over 2008-2030 to 3 bushels per year, slightly more than a 75% increase compared to the 1960-2007 trend (3.0/1.7 = 76%). Note that this is about the same percentage change as the last major shift in trend yields that occurred around 1960 (1.7/1.0 = 70%). This would result in a state-average trend yield of about 225 bushels per acre in 2030. The third and final scenario is based on the much publicized goal of a 300 bushel per acre trend yield (Fitzgerald 2006). In order to achieve that goal by 2030 the rate of growth in trend yields for Illinois would have to be 6 bushels per year, or about 250% higher than the trend over 1960-2007.[4]

Comparison of the trend yield projections to the historical record of Illinois corn yields suggests two important conclusions. First, reaching a trend yield of 300 bushels per acre in 2030 would require a rate of growth that is unprecedented both in terms of magnitude (6 bushels per year) and change from the previous rate (250%). Second, a jump in the trend yield growth rate to 3 bushels per year is within the range of historical experience since 1940.

FINAL THOUGHTS

It is interesting to consider the possibility that something of a historical cycle also may be at work. To begin, note the following prescient statement by Professor Louis Thompson at the end of his famous 1969 article on weather, technology, and corn production:

> *It is also significant that weather variability (affecting corn yields) has gradually decreased since 1930. As a consequence, there has been a decrease in year-to-year variations in corn yields. This trend in the improvement of weather and decrease in corn yield variability should be extrapolated with caution, however, because we may be near the end of a cool period occurring between periods of warmer than normal weather. Records in the U.S. Corn Belt indicate irregular cyclical weather, with periods of warmer summer weather alternating with periods of cooler summer weather. During this century, the decades of the teens, '30's, and '50's have been characterized by warm dry summers. If such a pattern persists, one might expect warmer and drier summers in the U.S. Corn Belt in the '70's and a temporary halt in the uptrend of corn yields.* (p. 456)

Writing a few years later in 1975, Professor Thompson made the following observation on the importance of weather for crop yields:

> *There has been more than usual attention in the press to weather and climatic change since mid-1974. The United States had so little variability in*

[3] The trend yield growth rate shown in Figure 7 for 1960-2007 is 0.3 bushels lower than the growth rate shown in panel A of Figure 2. As noted earlier, the difference is due to the adjustment for weather effects in the trend estimate reported in Figure 2.

[4] Technically, the rate of growth would have to be 6.2 bushels per year to achieve a 300 bushel state-average trend yield in Illinois by 2030.

weather and grain production in the past two decades (until 1974) that an attitude of complacency had developed. There was frequent reference in the early 1970's to the fact that technology had increased to such a level that weather was no longer a significant factor in grain production. (p. 535)

More unfavorable weather for the development of corn eventually followed in 1980, 1983, and 1988. This further identified the 1960s through the early 1970s as a favorable period for corn, with Professor Thompson stating in 1990 that:

The trend was very steep from 1960 to 1972 because the favorable weather each year resulted in excellent response to increasing technology. (p. 89)

The obvious question is whether a parallel should be drawn between weather patterns over 1960-1972 vs. 1973-1995 and 1996-2007 vs. future years. Without taking a position on the existence of long-term weather cycles or the potential impacts of global warming, history certainly suggests a good deal of caution in projecting recent and favorable weather patterns into the future.

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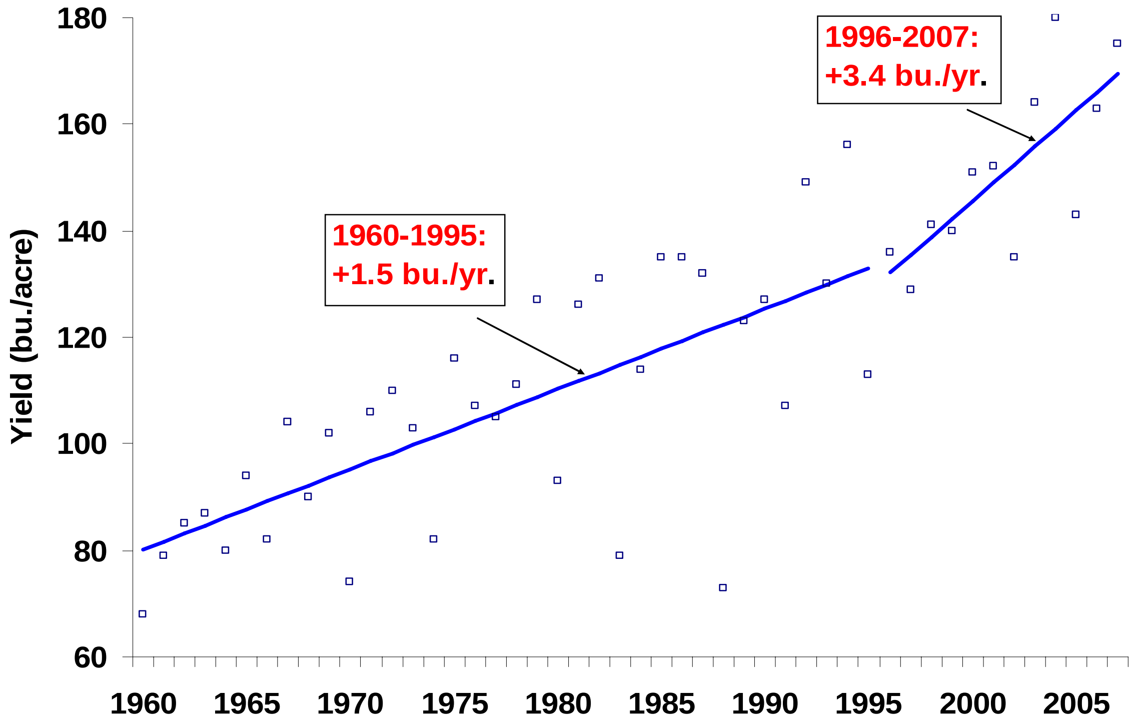


Figure 1. Illinois Corn Yields, 1960-2007

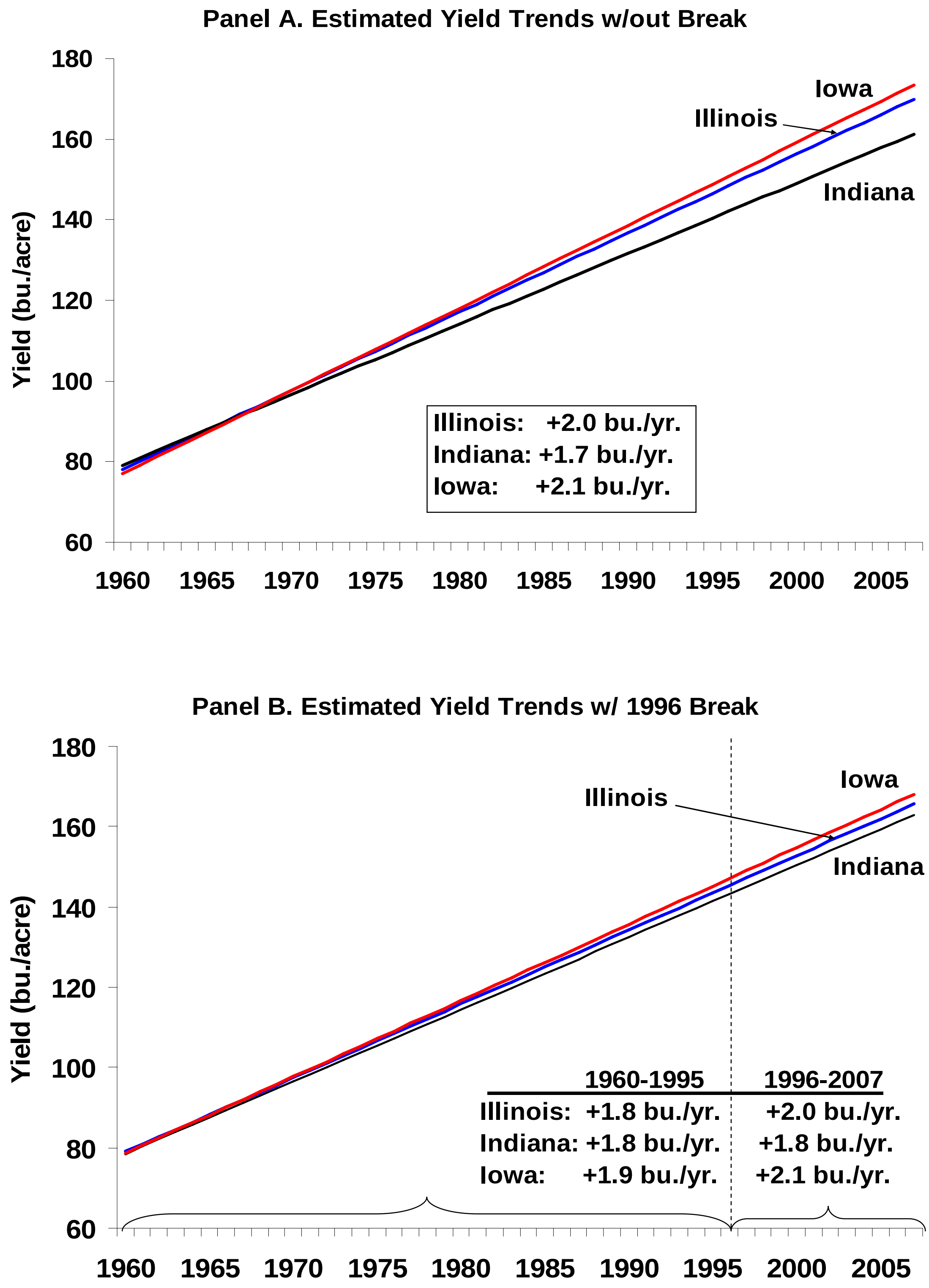


Figure 2. Estimated Trends in Illinois, Indiana, and Iowa Corn Yields after Adjusting for the Effect of Weather, 1960-2007

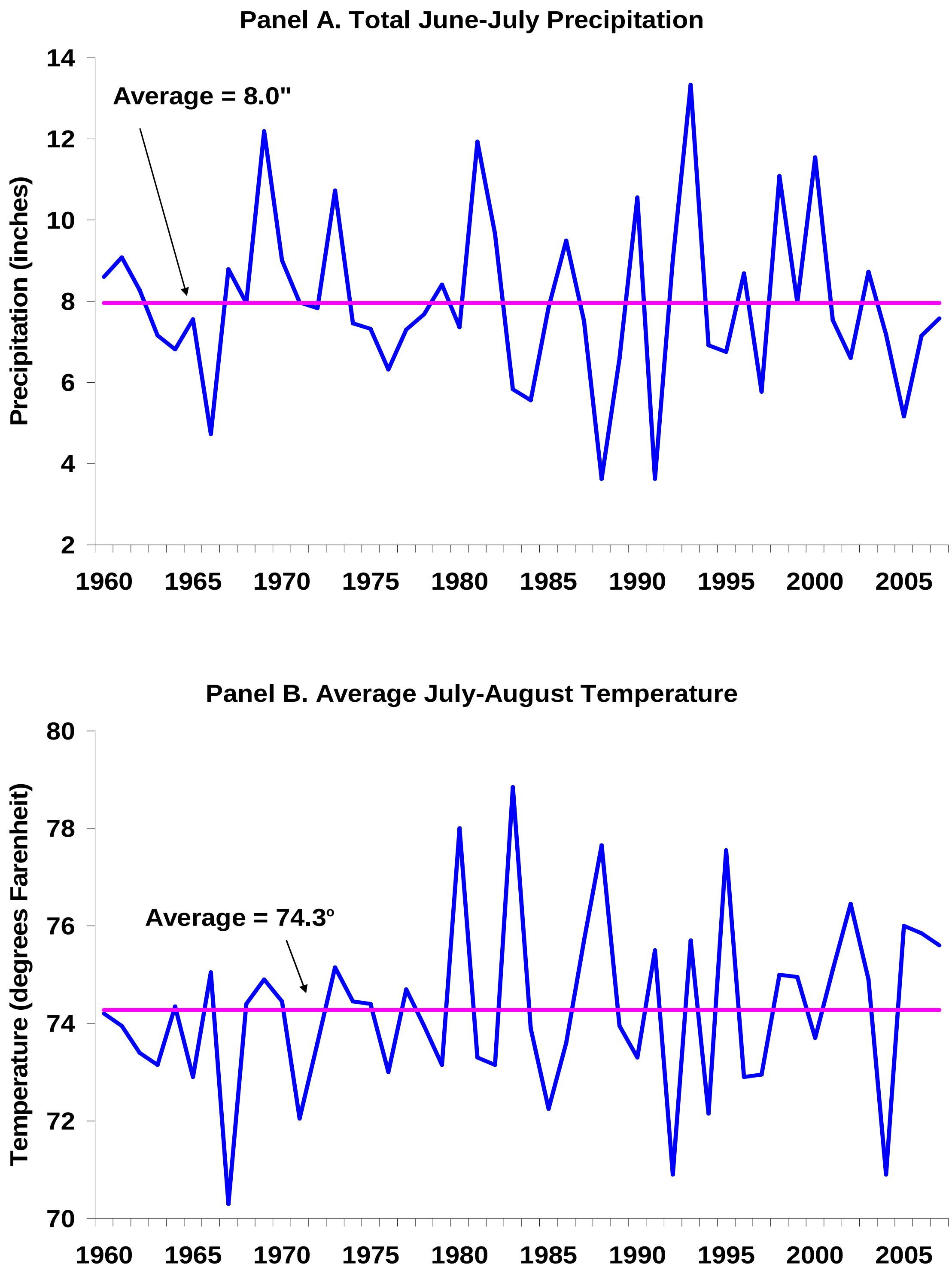
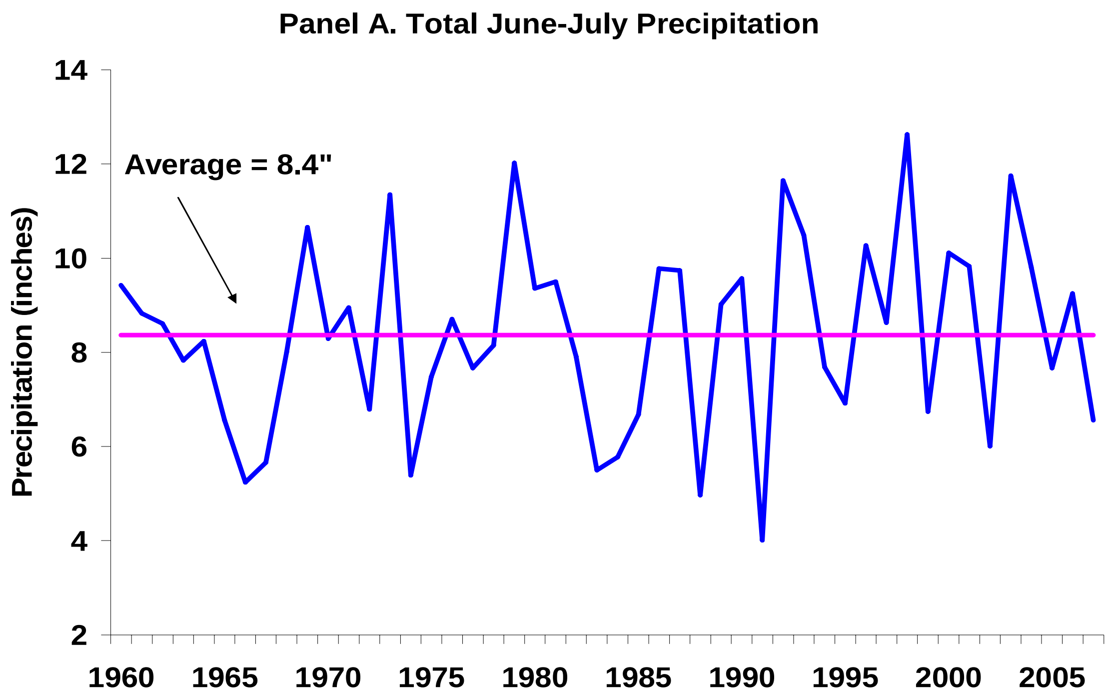


Figure 3. Key Illinois Weather Variables for Corn Production, 1960-2007



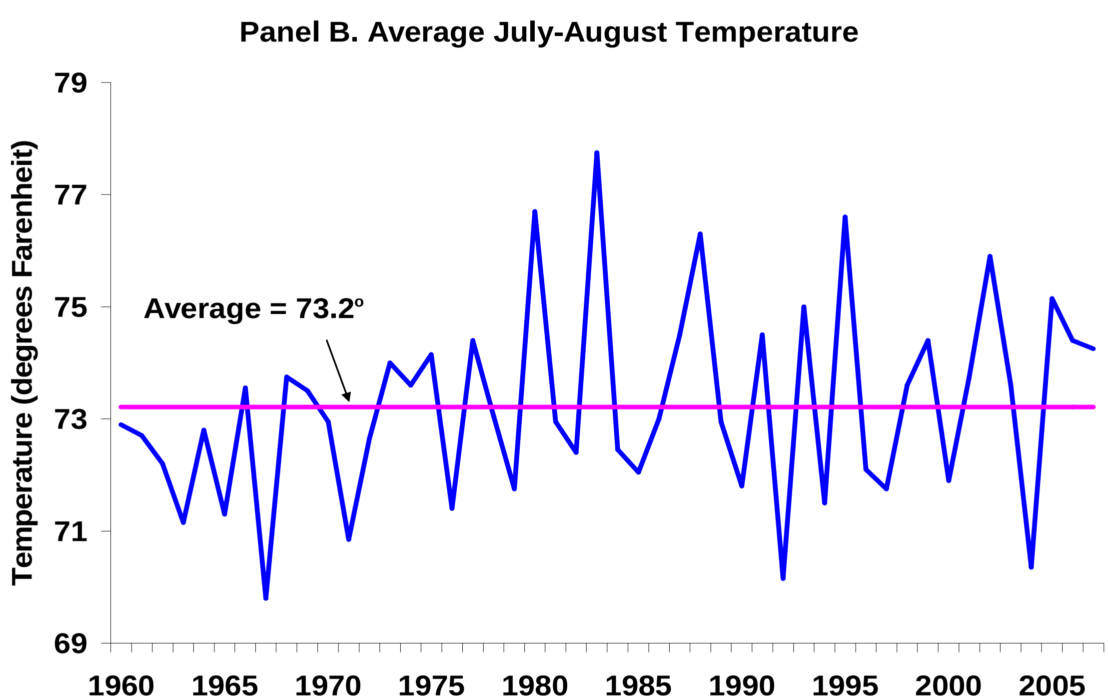


Figure 4. Key Indiana Weather Variables for Corn Production, 1960-2007

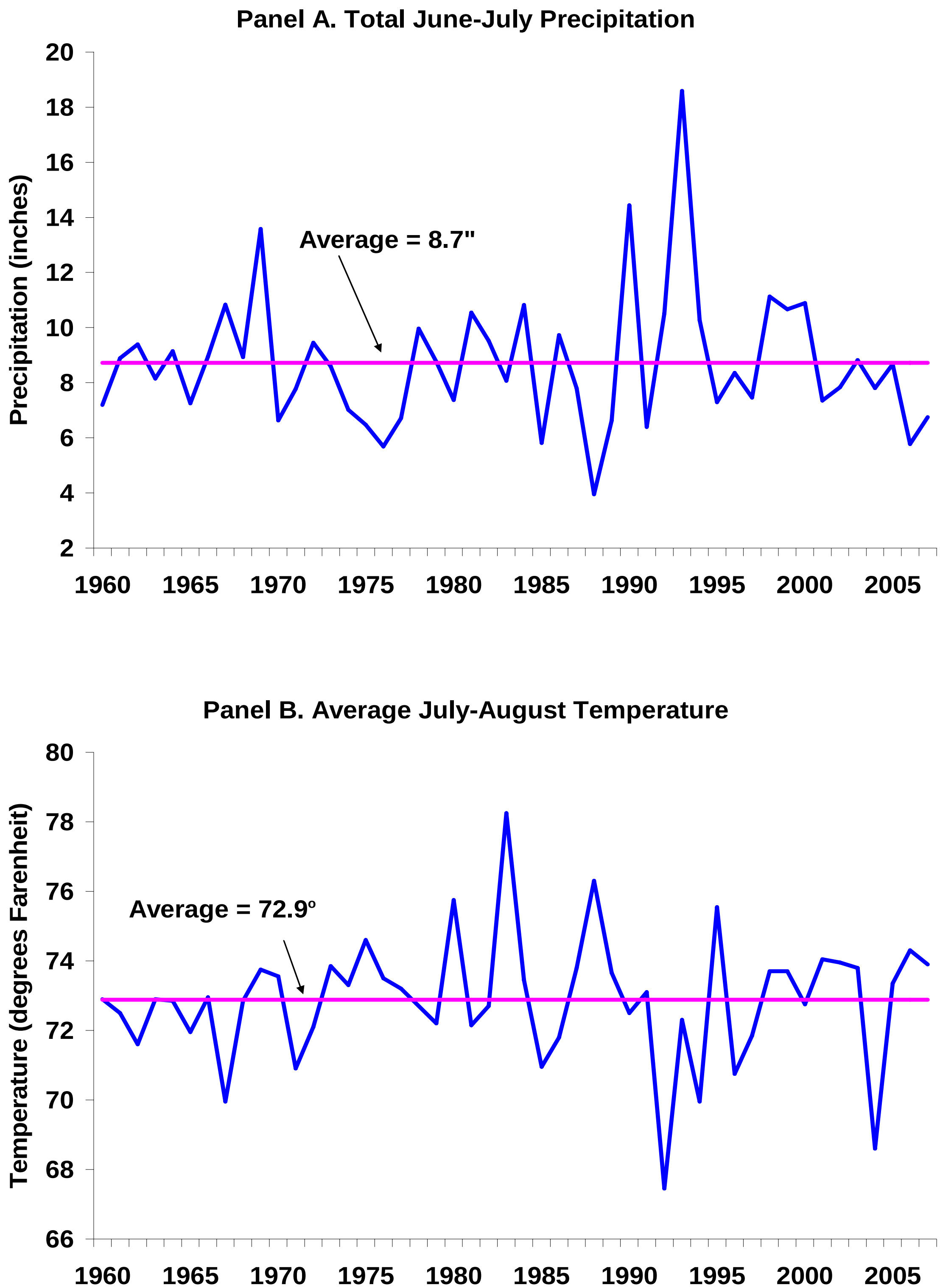


Figure 5. Key Iowa Weather Variables for Corn Production, 1960-2007

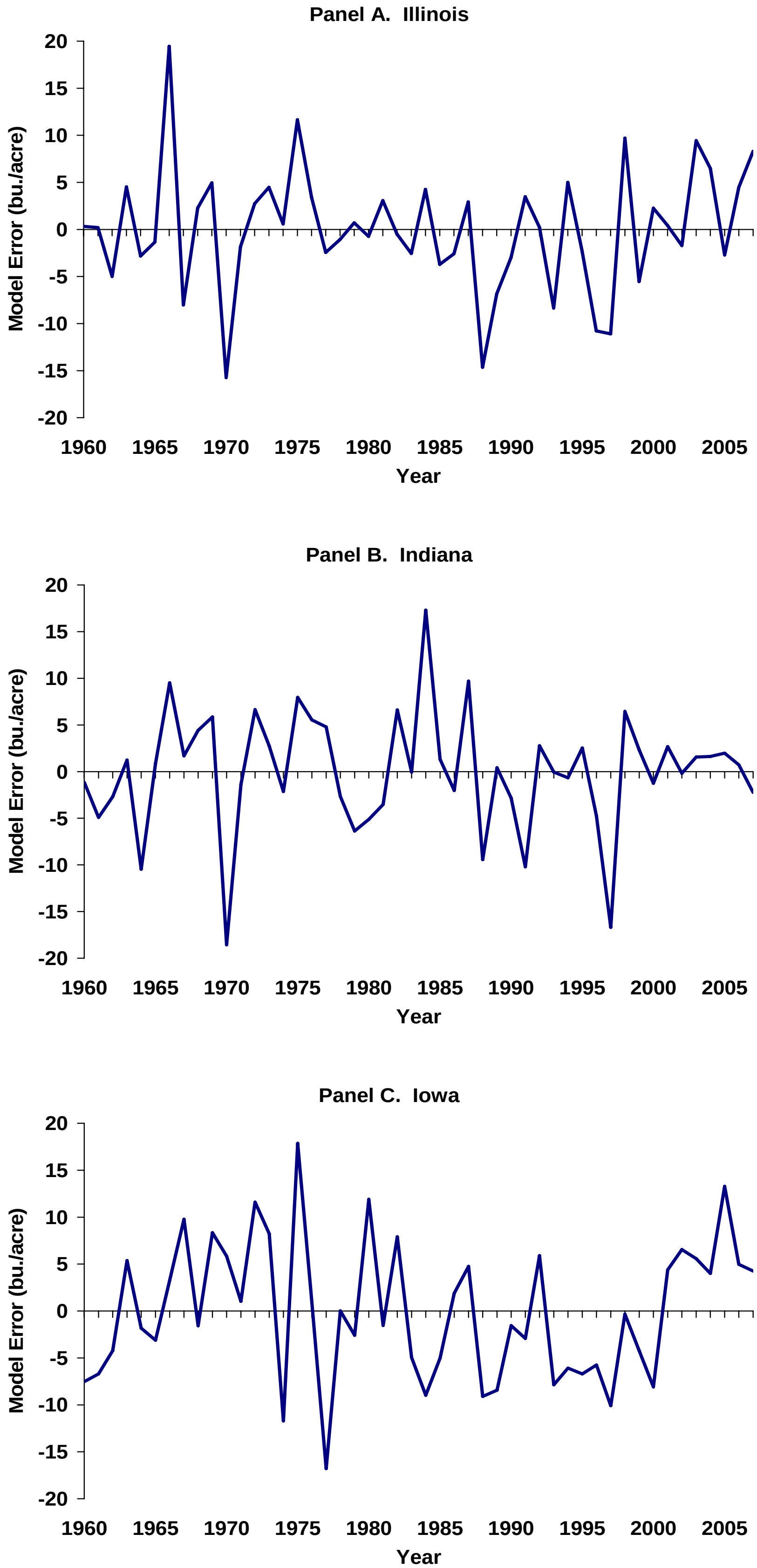


Figure 6. Weather and Technology Regression Model Errors for Corn Yields in Illinois, Iowa, and Indiana, 1960-2007

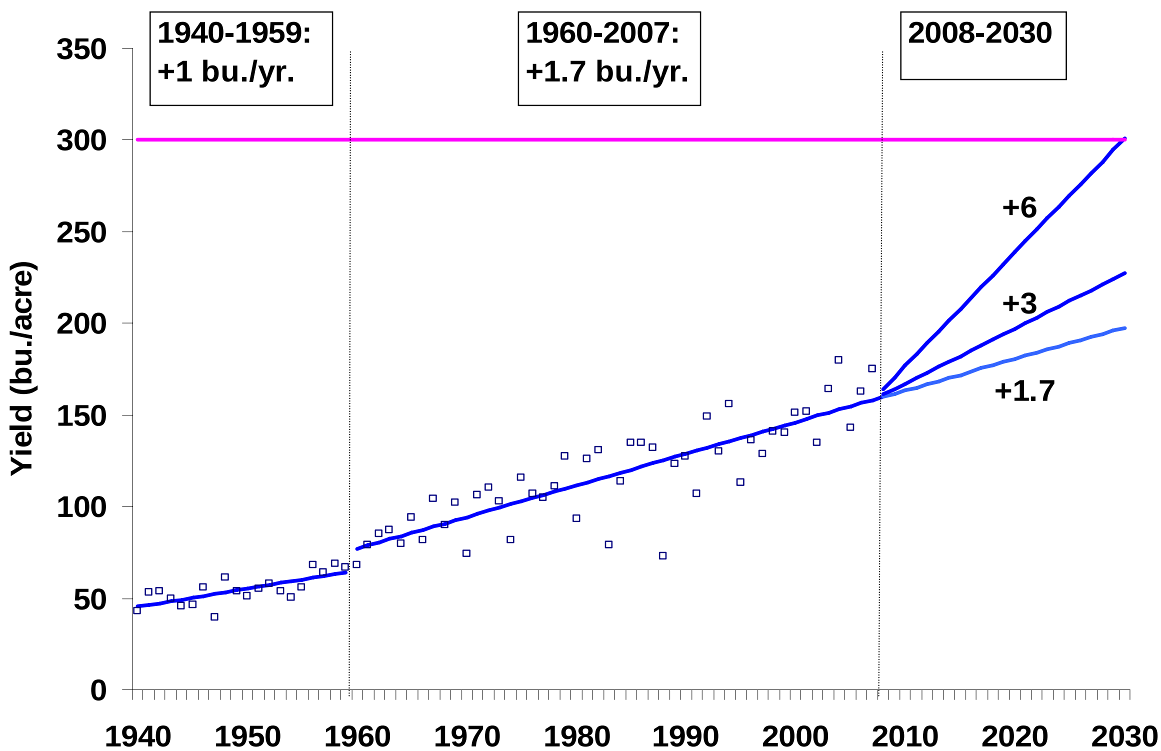


Figure 7. Illinois Corn Yields over 1940-2007 and Alternative Trend Yield Projections to 2030